Developing reservoir sediment ceramsite as a novel growing medium: I low temperature and anaerobic production

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Introduciton

The ceramsites are kinds of porous substances that have long been used as growing media for their durable, light weight, well-drained features. However, they usually show poor performances in water retention capacity, nutrient supplement since thay was sintered above 1200°C, which lead to well vitrification. In order to improve the disadvantages of ceramsites, we developed the biochar ceramsite made with the reservoir sediment and peanut shells. It was sintered at low temperature and N_2 atmosphere.

Research Goals

This work aimed to investigate the parameters which influence the biochar ceramsite characteristics. Three parameters were studied:

- sintering temperature
- the amount of biomass additives
- sintering atmosphere

Optimal formula for our product was also investigated.

Materials and Pretreatment

The sediment(S) is collected from Shimen Reservoir, Taoyuan city, Taiwan. We use the peanut shells as organic additives, provided by farmers in Changhua city, Taiwan. The sediment and the peanut shells were oven dried at 105°C until constant weight, crushed by the pulverizer (RT-N04, rongtsong) and sieved through a 0.25mm mesh for subsequent use.

All ceramsites samples were made by pelletizing. To determine the effects of biochar on sediment's clay-matrix, different amount of peanut shell—0 wt%, 5 wt%, 10 wt%, 15 wt%—were added to the sediment. During the process, the mixture were added with water to maintain appropriate plasticity and then shaped into 9.5mm sphere.

Production

The samples were heated at 105°C for 24 hours to reduce moisture content after pelletized. The samples were then subjected to firing process in the controlled atmosphere furnace. All the treatments were shown in Fig 1. Com-1 and Com-2 were respectively the foam stone and the lava rock which were often used as the growing media. The sintering condition is listed below:

- Sintering atmosphere: N_2 (N)/ Air(A)
- Sintering temperature: 600°C / 800°C / 1000°C
- Heating rate: 10°C / minute
- Residence time: 2 Hours
- Cooling rate: naturally cooled in the furnace

Fig. 1 The appearance of different treated ceramsite.

Characteristic Tests

We examined several characteristics of all treatments which were essential using as a growing media. For physical properties, as shown in Table 1., Maxium water holding capacity(MWHC), bulk density, aggregate stability and mechanic strength were investigated. As for chemical properties, pH(Table 1.), and nutrients—K+, Na+, Ca2+, Mg2+ —concentration(Fig 2) were also investigated. The textural and microstructural features of the samples were observed by Scanning Electron Microscope(SEM).

Result

As shown in Table 1, with more biomass addition, bulk density and mechanic strength decreased, while MWHC increased. This effect is due to the presence of the biochar. It played the role of the blowing agent and produce more big pores inside the SN ceramsite. When the sintering temperature is increased from 600°C to 1000°C, although the bulk density was not affected, mechanic strength significantly increased and MWHC decreased obviously, indicating an improvement of densification and melting due to sintering.(Fig 2 (a)(b)(c)) As for the sintering atmosphere, the SN ceramsites have obviously higher mechanic strength than the SA ceramsites when at 800°C. This effect may cause by Fe2+ which is generated in reducing atmosphere. Fe2+ incorporated into a vitreous matrix above 800°C, and let the formation of viscous phase be more extended.

Table 1. Bulk density, aggregate stability, mechanic strength,pH and Maximun Water holding capacity of biochar ceramsites (SN), references(SA, Com-1, Com-2) and raw sediment(RS). Standard errors which > 0.1 are in brackets.

	Sintering Temp	Biomass addition	Bulk Density	Aggregate stability (%)	Mechanic strength (Mpa)	Maximun Water holding capacity (%)
SN	600˚C	0%	1.02	100	0.41	20
		5%	0.85	99	0.30	30
		10%	0.85	99	0.27	36
		15%	0.71	99	0.23	45
	800˚C	0%	1.00	99	1.80	20
		5%	0.85	99	0.65	27
		10%	0.74	99	0.34	37
		15%	0.71	99	0.23	40
	1000˚C	0%	1.04	100	6.12	19
		5%	0.86	99	1.91	28
		10%	0.76	99	1.75	37
		15%	0.69	99	0.47	44
SA	600˚C	0%	1.03	87	0.36	NA
	800˚C	0%	1.01	100	0.78	20
	1000˚C	0%	1.06	99	9.95	16
Com-1	~1250˚C	NA	0.35	100	1.19	22
Com-2	~1400˚C	NA	0.83	100	1.65	21
RS	25	NA	0.97	0	NA	NA

Table 2. pH, nutrient(K^+, Mg^{2+}, Ca^{2+}, Na^+) concentration of biochar ceramsites (SN) and references(SA, Com-1, Com-2). Standard errors are in brackets.

	Sintering Temp	Biomass addition	pH	K^+ (cmol / kg)	Mg^{2+} (cmol / kg)	Ca^{2+} (cmol / kg)	Na^+ (cmol / kg)
SN	600˚C	0%	8.2(0.0)	1.34(0.1)	0.85(0.0)	5.04(0.0)	1.13(0.1)
		5%	8.1(0.0)	1.72(0.2)	0.78(0.1)	4.59(0.3)	1.63(0.5)
		10%	8.5(0.0)	1.88(0.1)	0.87(0.1)	5.04(0.4)	1.19(0.1)
		15%	8.7(0.1)	1.62(0.0)	0.65(0.1)	5.41(0.4)	1.21(0.1)
	800˚C	0%	9.4(0.0)	1.20(0.2)	0.83(0.1)	4.58(0.7)	0.96(0.0)
		5%	9.4(0.5)	0.91(0.1)	0.97(0.1)	5.88(0.4)	1.01(0.1)
		10%	9.9(0.1)	1.51(0.1)	0.96(0.0)	6.25(0.2)	1.32(0.1)
		15%	10.1(0.0)	1.91(0.4)	0.93(0.0)	6.03(0.3)	1.22(0.1)
	1000˚C	0%	9.1(0.0)	0.34(0.0)	0.6(0.10)	1.82(0.0)	0.57(0.1)
		5%	9.4(0.0)	0.57(0.1)	0.58(0.0)	1.91(0.1)	0.84(0.1)
		10%	10.3(0.0)	0.95(0.1)	0.95(0.0)	4.35(0.0)	1.13(0.1)
		15%	10.2(0.0)	1.25(0.6)	1.99(0.10)	4.00(0.1)	1.06(0.2)
SA	600˚C	0%	7.9(0.1)	1.84(0.6)	1.7(0.10)	5.61(1.1)	1.44(0.1)
	800˚C	0%	9.5(0.1)	1.25(0.2)	1.58(0.1)	5.47(0.5)	1.19(0.0)
	1000˚C	0%	6.5(0.1)	0.84(0.5)	0.25(0.0)	1.91(0.1)	0.48(0.1)
Com-1	~1250˚C	NA	6.5(0.4)	0.22(0.1)	0.09(0.0)	0.59(0.1)	0.15(0.1)
Com-2	~1400˚C	NA	8.6(0.0)	0.57(0.1)	0.82(0.0)	5.70(0.1)	0.76(0.1)
RS	25˚C	NA	7.6(0.1)	0.35(0.1)	0.92(0.2)	4.82(0.7)	0.16(0.0)

The biomass addition obviously led the raise of pH and K+, Mg2+, Ca2+ concentration. These elements were mainly provided by the peanut shell biomass. As for the sintering temperature, pH increased in all treatments when sintering temperature is raised from 600°C to 800°C. However, when sintering temperature is raised from 800°C to 1000°C, pH of SA decreased while SN unchanged. This effect may lead from the elements is Immobilized though the crystallization in the melt of complicated compunds. The similar phenomena can be seen in K+, Na+, Ca2+ concentration.

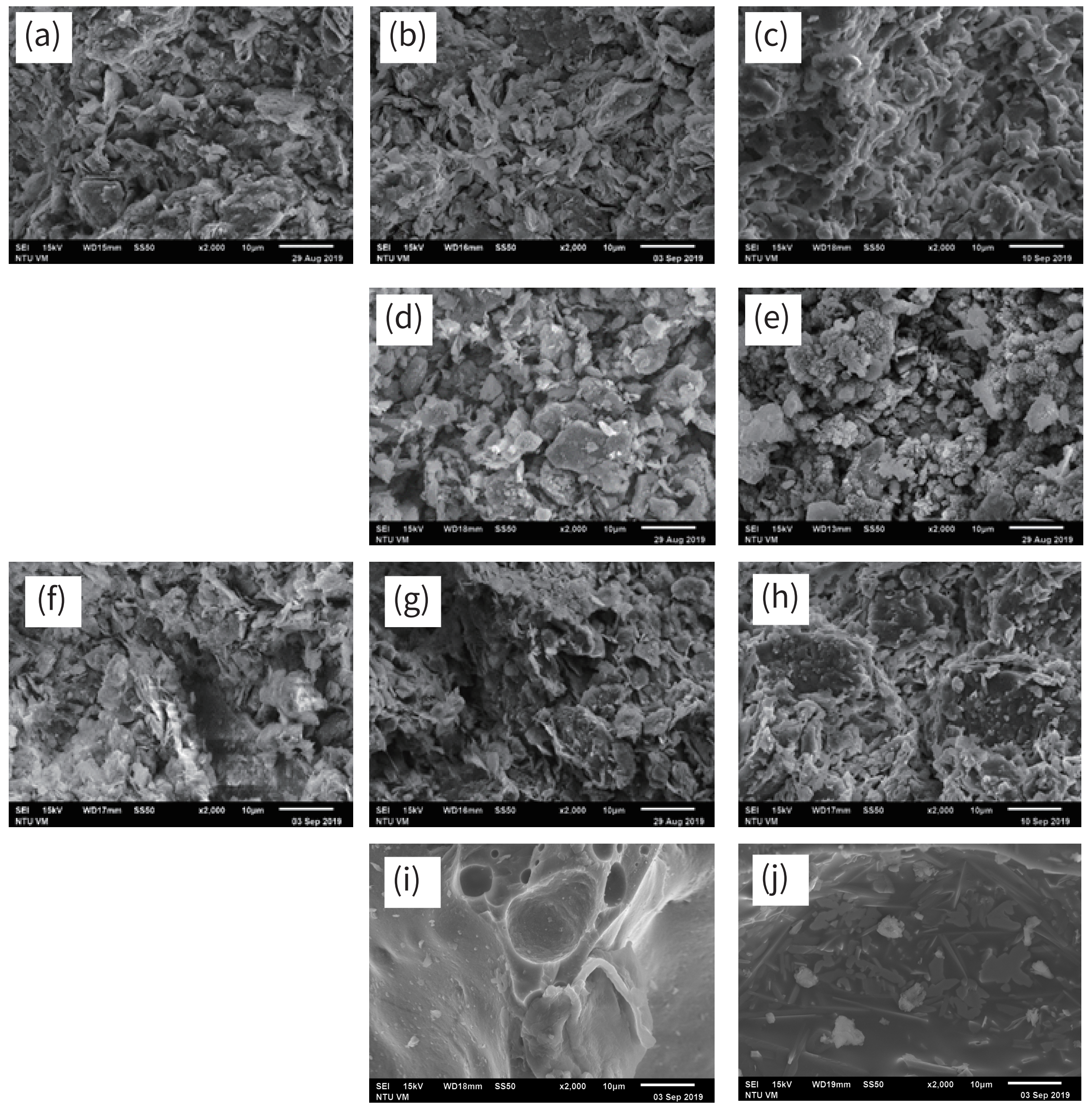

Fig. 2 The microstructure of (a)(b)(c) the corss-section of SN + 0% sintered at 600°C, 800°C, 1000°C, respectively . (d)(e) the corss-section of SN + 15% sintered at 800°C and at 1000°C. (f)(g)(h) the corss-section of SA + 0% sintered at 600°C, 800°C, 1000°C, respectively. (i)(j) the cross-section of Com-1 and Com-2

Conclusion

The study shows that ceramsites produced by the reservoir sediment and peanut shells can improve the disadvantages of commercial ceramsite used nowadays. The ceramsites sintered in N2 atmosphere (SN) retained peanut shells additives as the form of the biochar. Comparing those sintered in air atmosphere, SN with 5% or more additives have better water holding capacity and lower bulk density, and keep more nutrients that the plants need. The sintering temperature is also a crucial parameter. When the sintering temperature increase, it attributes to two counter-acting phenomena: (1) MWHC and the nutrient concentration of SN decrease (2) stimulating minerals to decompose or melt which lead to high mechanic strength.

Comparing with Com-1 and Com-2, we suggest that SN + 5% - 800°C or SN + 10% - 800°C would be appropriate for producing our product.